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Effect of Waterproofing Systems and Materials on Environment

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Abstract

The prime function of waterproofing of concrete is to stop ingress of water into the concrete which directly increases the durability of concrete. Use of waterproofing materials also effects the environment in a positive way by reduction in wastage of water, prevents wastage of resources, minimizes health hazards and improves internal air quality of concrete structures. Numerous waterproofing materials and systems are available in market. Waterproofing systems are broadly classified into modified cement mortars, membranes and coatings. Each of these types and their subtypes have been critically reviewed to document their advantages and disadvantages. An ideal waterproofing system and material is still a distant dream to find.

Keywords: *Environmental Effects; Waterproofing materials; Waterproofing Systems*

1. INTRODUCTION

Waterproofing is a basic requirement for all types of structures like residential, commercial or industrial buildings. Waterproofing compounds are used primarily to stop ingress of water into the concrete but these directly or indirectly helps in nourishing the environment too.

Concrete waterproofing aids in preserving the environment by reducing the wastage of water. Waterproofing compounds like plasticizers, super plasticizers have been reported to reduce the consumption of water by 5 to 30% of the total water used at the time of mixing and reduces the w/c ratio without altering the workability of a particular concrete mix resulting in less permeable, denser concrete/masonry structures (Shetty,2005). Amount of water saved throughout the world in this era of large scale of construction can be idealized. Waterproofing of concrete also prevents wastage of resources by reducing corrosion of steel and concrete spalling in RCC Structure caused due to moist environment of concrete, taking a toll at the overall durability of structure and can be avoided by use of some waterproofing compounds. It improves the pore structure and also provides water resistant environment for the steel. The increase in durability results in increasing of overall life of structure which helps in prevention of wastage of resources used in construction. Waterproofing of concrete also minimizes health hazards mainly caused due to dampness of concrete. Dampness of concrete offers favorable conditions for the growth of mosquitoes and otherinfective microbes which are the main causes for fatal diseases like Zika Virus, Malaria, West Nile virus, Dengue fever, Yellow fever, chikungunya etc. Many epidemiological studies have shown linkages between dampness and adverse health effects. Waterproofing helps in reducing permeability of water and moisture transmission, thereby helps to keep the concrete almost damp free which in turn helps tofight the adverse effects of dampness on human health. Waterproofing also improves internal air quality of buildings. The degraded quality of air caused by dampness and mould growth within the buildings has the adverse effects on human health manifests in various forms ranging from irritation of mucous membrane, respiratory symptoms and infections to chronic diseases like asthma and allergy. Etiopathogenesis of these diseased conditions predisposed by dampness is still properly documented (Udofia *et al.* 2014). Water proofing of concrete enhances internal air quality and eliminates to a greater extent the frequent repairment and maintenance of the buildings. Aesthetic look of the buildings could also be maintained for much longer time by using waterproofing materials. Different types of

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waterproofing materials and systems are discussed below:

2. WATERPROOFING SYSTEMS AND MATERIALS

Numerous waterproofing systems and materials are available in the market. These waterproofing systems and materials have been classified and represented in the following figure.

2. 1 Modified Cement Mortars

Good compatibility with cement makes it preferable over other waterproofing systems. This ensures no passage of water through matrix.Such motors are applied over rooftops, toilet floor, basement and wet areas to keep concrete dry. Materialsused being economical makes it cost effective andsurface preparation is not compulsory for its application.Cement mortars to which waterproofing chemicals are added are such systems. These modifiers are broadly classified as polymeric and non-polymeric materials.Non-polymeric integral waterproofing materialsin the form of dry powders or liquids such as plasticizer, mineral admixtures, pore blockers, repellents function when mixed with cement mortar.

Polymeric based waterproofing materialsbond well to be base concrete, have low permeability, good workability and strength and low shrinkage providing effective and long-term solutions.Latex emulsions of styrene butadiene rubber (SBR), acrylics, acrylonitrile rubber and styrene acrylic ester are the most effective polymer-based modifiers.

2.1.1 Non-Polymeric Modifiers

2.1.1.1. PLASTICIZERS

Plasticizers allow a reduction in water content for the given workability, or give a higher workability at thesame water content, are termed as plasticizing admixtures. The advantages are considerablein both cases: in the former, concretes are stronger, and in the latter, they are more workable. Plasticizers based on lignosulphonates increase the compactness of the cement mortar by improvingthe flowability or workability by releasing the water present between the cement particles due to the deflocculating of the cement particles through electrostatic repulsion (Jayashree *et al.*2011). Mechanical properties of lignosulphonate modified cement mortar are found to be almost similar to unmodified cement mortar.Integral waterproofing modified cement mortarsmay be the most cost-effective modifier of cement mortar when applied only in indoor areas, where there is no exposure to UV light or wetting- drying cycles (Krishna *et al.*2012).

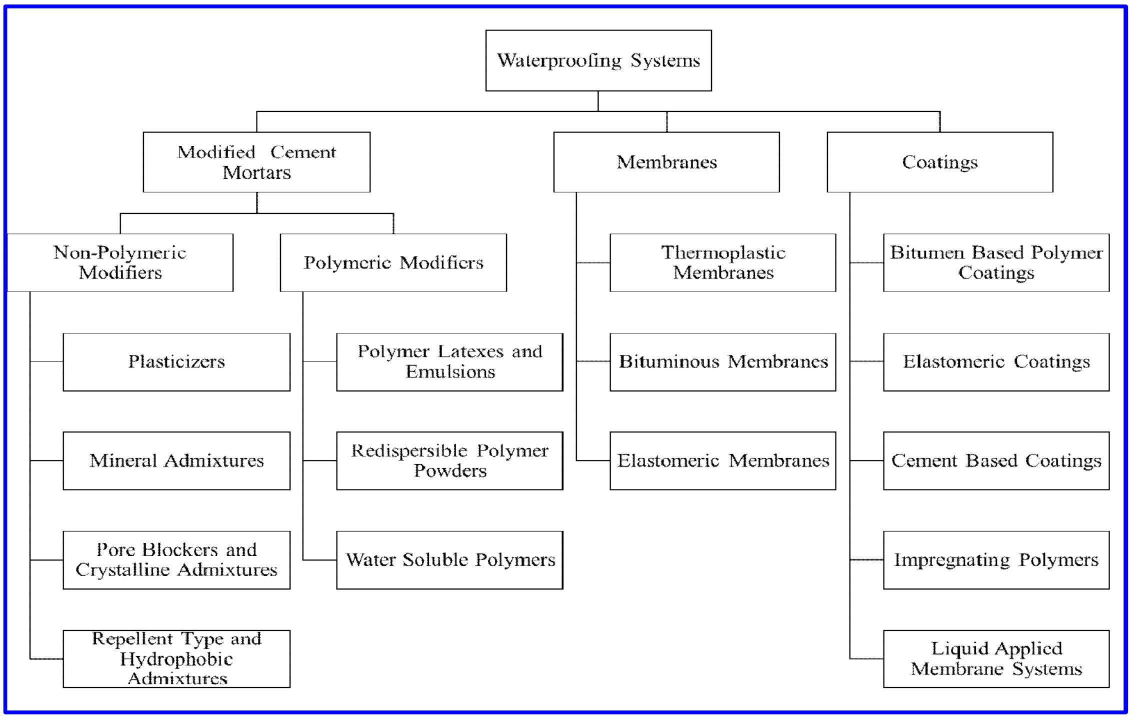

Figure1: Different types of Waterproofing Systems and Materials

2.1.1.2 Mineral Admixtures

Mineral admixtures help in improving the quality of concrete. Use of mineral admixture decreases the permeability, retards or accelerates the initial setting time, prevents shrinkage, reduces segregation, increases overall strength of concrete etc. Some of the commonly used mineral admixtures are silica fume, fly ash, rice husk ash, ground granulated blast furnace slag etc. The dosage of each mineral admixture varies.

2.1.1.3 Pore Blockers and Crystalline Admixtures

Water permeation through mortars can be reduced use ofadmixtures such as finely divided inert fillers and wax or bitumen emulsions which fill the microscopic pores in the hardened cement paste.The wax and bitumen emulsions occupy the capillaries acting as plugs to prevent further permeation of waterwhen subjected to water under pressure (chan*et al*.1999*)*. Impermeability of concrete is expected to improve by the reaction of crystalline admixtures with calcium hydroxide in the presence of water forming water insoluble crystals that fill, and plug pores and microcracks in the concrete(Ramachandran,1996).

2.1.1.4 Repellent type or hydrophobic admixtures

These are admixtures which reduce permeability including soaps based on calcium, potassium, ammonium and butyl salts of long chain fatty acid derivatives, such as stearates, oleates, and caprylates and petroleum derived materials.Water-repellent salts are formed by the reaction of calcium hydroxide in the hydrated cement paste acting as barriers inside the pores. The incorporation of such productsprevents water from penetrating into the concrete structureand causes water to bead on the surface.

2.1.2 Polymeric Modifiers

General mechanisms

Glass transition temperature, minimum film forming temperature, viscoelastic behavior, the minimum dosage in the mix, its compatibility with cement mortar and cost effectiveness arethe important considerations for a polymer to be used as a modifier of cement mortar (Manjrekar,1995). Both cement hydration and polymer film formation should occur together to yield aninterpenetrating network of both the phases,when the polymer is incorporated in the cementitious matrix of the mortar and concrete (Ohama,1998). The mechanism of polymer modification of the cementmortar can be described in three steps and comatrix phase formation has been illustrated by a simplified model shown schematically in below figure:

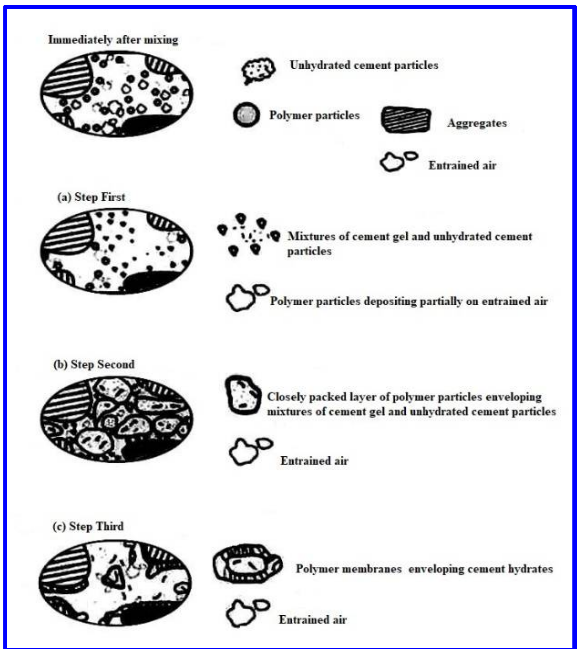

Fig. 2: Typical model of formation of polymer cement co-matrix

Immediately after mixing with water,a mixture of cement and polymer particles dispersed in water around the aggregates.

a) Deposition of polymer particles begins on the surfaces of the unhydrated cement particles and the hydration products.
b) A dense layer of polymer particles is then coated onthe mixture of hydration products and unhydrated cement particles.
c) The hydration products are enveloped by polymer films,in the third step.

The minimumfilmforming temperatureof the polymer and the relative humidity of the surroundingatmosphereare the chief factors on whichthe film formation of a polymer depends (Beeldens *et al.* 2005*)*.

2.1.2.1 Polymer latexes and emulsions

These are prepared by emulsion polymerization of polymer particles dispersed in an aqueous medium. Elastomeric latexes, thermo-plastic latexes, thermosetting latexes and bituminous latexes arethe polymers incorporated as latexes in cement mortars. The workability of the cement mortar can be increased orwater/ cement ratio (w/c) for the same workability can be decreased by the incorporation of the latex (Mirza *et al.*2002*)*. The modification of cement mortar and concrete have been done with latexes for improving the adhesion with the base concrete, and to prevent the permeation of water and external chemicals into the cement matrix (Afridi *et al.*1995).

2.1.2.2 Redispersible polymer powders

The polymer latexes are spray dried to obtain powders with particle sizethe order of 1-10 µm. Before mixing withwaterthese are dry blended with cement.Some of the polymers included in this category arepoly (ethylene-vinyl- acetate) (EVA), poly(styrene - acrylic ester) (SAE), poly (acrylic ester) (PAE), polyvinyl acetate(PVA) and vinyl acetate and versatate copolymer (VA/VeoVa). Though they are employed in similar applications as latex modified cement mortars, they are more popular in cementitious tile adhesives.

2.1.2.3 Water soluble polymers

Cellulose derivatives, polyvinyl alcohol (PVAl) and polyacrylamide (PAN) are commonly used water-soluble polymers. They are added to the cement mortar or concrete either in the powdered form or as aqueous solutions duringmixing. More hydration is observed after 90 days for 1% polyvinyl alcohol-acetate, methylcellulose and hydroxyl ethyl cellulose modified mortars,in spite of an initial retardation of hydration (Knapen and Van Gemert,2009). This attributes to a better dispersion of the cement particles in the mixing water on addition of these polymers. Polymer bridges develop between the layered calcium hydroxide crystals, gluing the layers together and strengthening the microstructure. However, a drastic decrease in the flexural and splitting tensile strength is also observed during intensive storage at high relativehumidity or under water.

2.2 Water Proofing Membranes

Sheets that are applied or pasted over a concrete surface to act as a covering to protect a concrete structure from moisture are known as membranes. Seamless and essentially watertight, non-slip and durable surfaceis provided by the ideal membrane-based waterproofing system provides a (Caputo and Hans Peter,1987).

Types of waterproofing Membranes

Flexible membranes, completely bonded or membranes that adhere to joints of concrete structures are bonded membranes. In case of a possibility of penetration or a damage and to prevent lateral water migration or leakagea fully bonded system is employed. At the joints the membranes are adhered by self-adhesive strips present longitudinally on the membranes. A waterproof membrane system consists of an embossed membrane, such as flexible polyolefin, that is laminated with a unique sealant grid and reinforced with a non-woven fleece. Fordamp-proofing these fully bonded systems are applied to protect a structure from rising humidity, protecting concrete against aggressive environment in theground and waterproofing against hydrostatic pressure. Installation is easy and safe, as no welding or primer is used. The corners are initially sealed or formed with suitable adhesive waterproofing tapes and then bonded to membranesduring the installation of a bonded membrane.

Almost complete durability and reliability requirements of deep foundations like basements for high rise buildings, cut & cover tunnels and metro stations is provided by partially bonded membrane systems, such as loosely laid PVC or FPO membrane system with compartments and injection back-up. Prevention of water migration, possibility of water migrating below the whole raft, between the whole retaining wall and the waterproofing membrane, thus a complete failure and leakages everywhere from the raft and walls at the weak points of the concrete are checked by employing this back up system.Complete backup mechanism to prevent leakages, versatility and earthquake resistance are some properties of partially bonded membrane systems. These could be used forgreen roof installation and fasteners are employed to fix the membrane on the concrete slabs.The main types of commercially available membranes are discussed below.

2.2.1 Thermoplastic Membranes

This category comprises of loosely laid or self-adhering waterproofing membranes attached to a surface using adhesives, mortar, tape, straps, anchors, plastic welding or fasteners. Sheets or panels are overlapped and fused together by heating and subsequently converted to solid upon coolingas thermoplastic membranes change from solid state to semi-solid state on heating. Thus, a monolithic, continuous sheet membrane is formed.The polyvinyl chloride (PVC) or vinyl membrane system is the most well-known of the available thermoplastic roof membranes. PVC membrane systems may be non-reinforced or reinforced with glass fiber or polyester fiber.

2.2.2 Bituminous membrane

Commonly used in waterproofing are Styrene-butadiene-styrene copolymer (SBS) and atactic polypropylene (APP) polymer modified bituminous membranes. To obtain high tensile strength, tear and puncture resistance.polymerized bitumen is coated with dimensionally stable non-woven polyester / fiber glass carrier. These are employed as flexible sheets for waterproofing of concrete bridge decks and to prevent water infiltration through the pavements and basements. These membranes are located on the positive side of the

structure to prevent the ingress of water to the surface from the ground, while waterproofing basements.

2.2.3 Elastomeric Membrane

Preparation of these membranes is done by modifying thermoplasticpolymers with a suitable elastomer to enhance the movement and flexure of the resulting membrane. Being ready to use, good adhesion onto the base concrete in both vertical and horizontal applications are advantages of elastomeric membrane systems, thus preventing water penetration, and attack when exposed to chemicals and moisture(Nair and Gettu,2016).Styrene butadiene styrene and rubber modified self-adhesive membranes are commercially available with an adhesive on one side for the membrane to bond to the concrete surface.

2.3 Waterproofing Coatings

To prevent permeation of water and any soluble salts from penetrating the concrete which prevents the corrosion of reinforcing steel and interaction with the cement particles, waterproofing coating systems are mostly employed. Early deterioration of concrete structures exposed to adverse topographic conditions, severe ground and ambient salinity and high temperature-humidity system is prevented. Good adhesion to the substrate, permeability to vapor and crack bridging ability without decreasing the alkali resistance of the substrate are some advantages of waterproofing coatings. Waterproofing coatings can be employed in areas, such as swimming pools and terrace waterproofing. Most coating systems are based on epoxy, silicone, urethane, acrylic rubber, acrylic resin, polyester and polymer-modified cement and mortar, depending on the conditions in which the coating might be exposed.

2.3.1 Bitumen based polymer coating

These are a mixture of bitumen, mineral fillers and polymers. Either elastomeric polymers, as in the case of styrene butadiene styrene copolymer, or plastomeric polymers, as in atactic polypropylene and acrylics are commonly used polymers. Even at low temperatures addition of polymer to bitumen improves the flexibility and provides almost impermeable barrier against ingress of water especially in pavement in bridges, industrial wash rooms, refurbishing of old bituminous roofs and tunnels. This system is employed on structures in underwater conditions, like pipelines, foundations, tanks, sewage works, effluent plants, docks, harbor installations, etc.

2.3.2 Elastomeric Coating

A shield preventing the permeation of chloride ions into the substrate is formed by coatings such as acrylic resin solutions, water-repellent silicon resins, certain types of silane resins, acrylics, and polyurethanes. Coatings based on silicone can be applied with roller, power roller, brush, or spray as they are water based. Minimum two coats are recommended to be applied for lasting weatherproofing performance. Stability during weathering conditions, resistance to sunlight, ozone, rain, snow, and temperature extremes, protection against cracking, chalking, peeling, and blistering are some advantages of elastomeric coatings. To prevent leaching of chemicals from concrete before application of silicate-based coatings to precast concrete slabs the basic precaution to be taken is pre-treatment of the substrate.

2.3.3 Cement Based Coatings

A blend of cement, fine graded sand, polymer based waterproofing additives and sometimes fibers based on polyethylene, polypropylene, alkali resistant glass and acrylates are cement based coatings which are used to control cracking due to shrinkage. The regulation of water added to apply the coating on the defective surface is the main precaution while using this system.

2.3.4 Impregnating polymers

Low viscosity monomer- activator systems can be impregnated into precast concrete and the monomer polymerized by means of microwaves or high temperature. A protective coating on the concrete surface is formed which improves the mechanical properties of the concrete and also durability during freezing and thaw ingaction and on exposure to a severe environment (Nair *et al*. 2010). Though the chief drawbacks include a long reaction period to form a silicone resin network, still silicon resin-based water repellent systems are also impregnated into the concrete

2.3.5 Liquid applied membrane systems

Polymer coatings of acrylics or unsaturated polyesters that are reinforced with glass, polyester or fiber glass make upliquid applied waterproofing membrane systems. Thickness of liquid membranes varies from 0.7 to 1mm, and on siteare applied by brush or spray application of liquid polymers/ acrylics/ polyurethanes, etc. These membranes are generally reinforced with glass fibers for increasing the durability. For polyurethane modified acrylic dispersion basedliquid membranes, to improve the performance against carbonation it is essential to control the thickness of the waterproofing membrane and maintain the waterproofing topcoat (Tsukagoshi *et al.* 2012*)*.

3. CONCLUSION

Waterproofing for all the concrete structures is mandatory to increase their life, to conserve the resources, to preserve the environment and to safeguard

the human as well as animal health. Critical review of all the available waterproofing systems and materials lead to the conclusion that an ideal system and material for waterproofing is yet to come into existence. An ideal waterproofing system/material having the properties of high efficacy, readily availability, easy applicability, cost effectivity and long durability needs to be developed on high priority basis, for which concrete and collective efforts are to be put into place.

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